Peracetic Acid Disinfection – An Alternative Wastewater Disinfectant:
Can It Work for You?

Brian A. Hilts, PE

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CDM Smith

Energy Management Initiative – Wave Five
Tennessee Water and Wastewater Utility Partnership

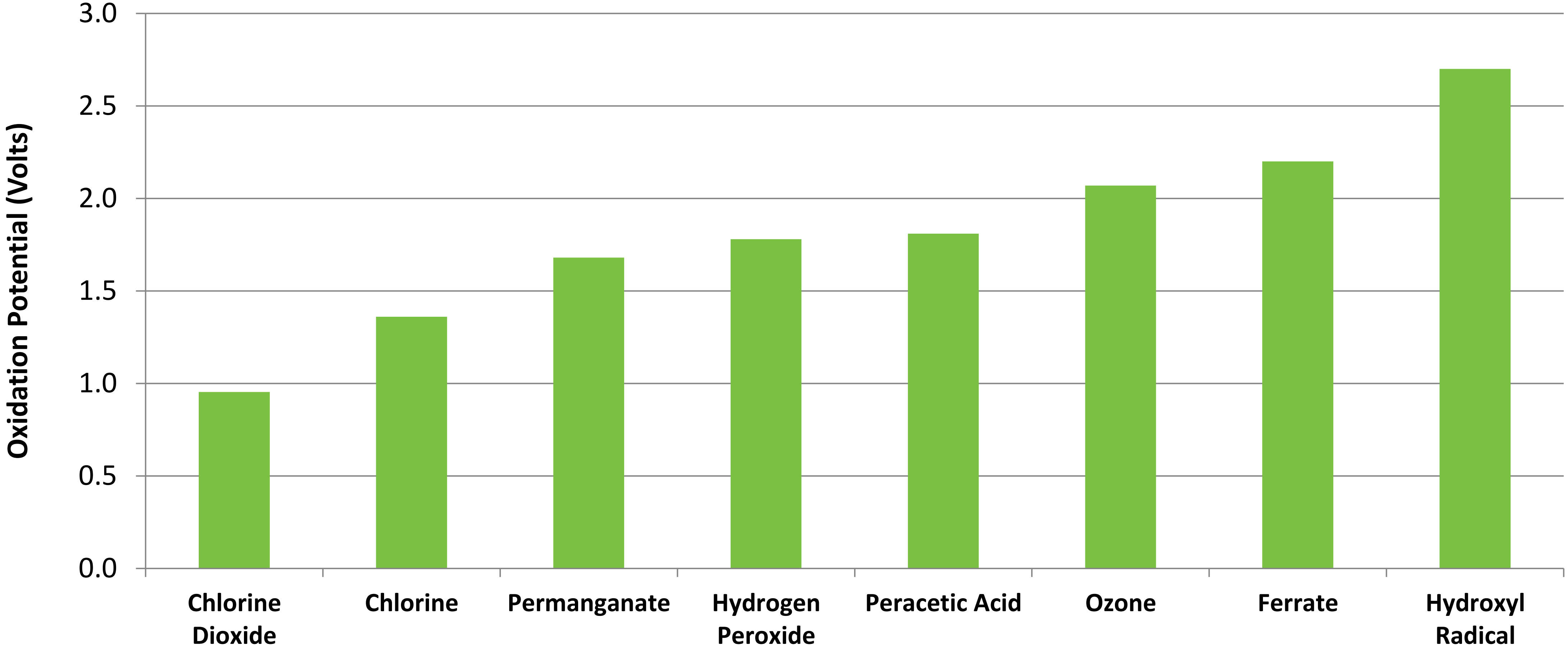
Outline

- Background of PAA
- Evaluating PAA
- Design Considerations
- Implementation
- Questions

Background
History of Usage

- Disinfection for the food industry (early 1990's)
  - Hard surfaces in dairy, beverage, brewery, winery, egg, food processing plants and other clean-in-place (CIP) processes
- Food, meat, fish, fruit and vegetables (early 2000's)
  - Food products can be put through spray, dip and brush wash
- Pulp & paper
  - Used to eliminate odor in paper mills and as a bleaching agent for pulp and paper
- Laundry (early 2000's)
- Medical device sterilization (1980's)
- Cooling towers water treatment (1990's)

Background
WRRF Disinfectants



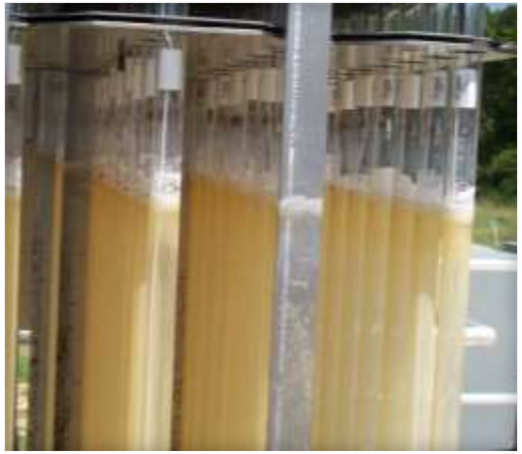
Background
Chlorine Disinfection & Challenges

- Chlorine is still the most commonly used method of disinfection often due to cost
- Chlorine Challenges
  - Risk management for gas
  - Short shelf-life for liquid
  - Increasing nutrient limits
    - Disinfection by-products when high free chlorine doses are used
    - Partial nitrification and nitrite lock

Background

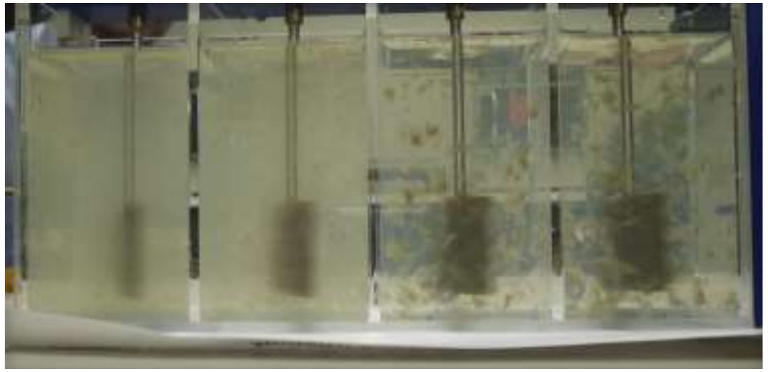
UV and Ozone Disinfection & Challenges

Operations



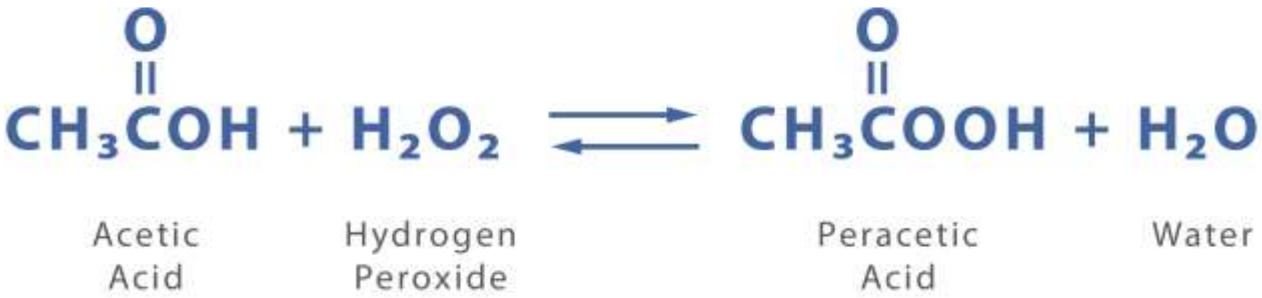
High oxidant demands and industrial discharges

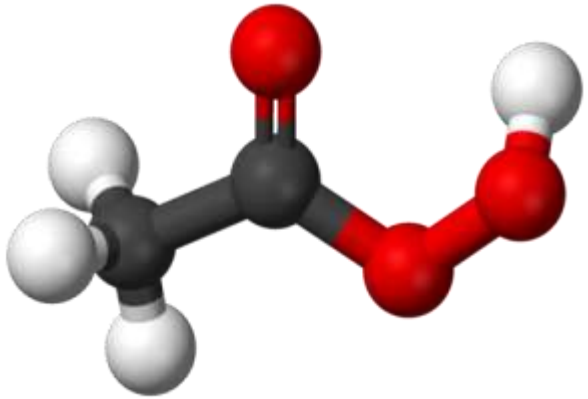
CSOs and wet-weather flows



Background

What is PAA?





Parameter	Value
Appearance	Colorless Liquid
Odor	Pungent, vinegar-like
Specific Gravity	1.16 g/cm^3
Boiling Point	108°C (226°F)
Vapor Pressure	22 mm Hg at 25°C
Freezing Point	-49°C (-59°F)
Shelf Life	~12 months

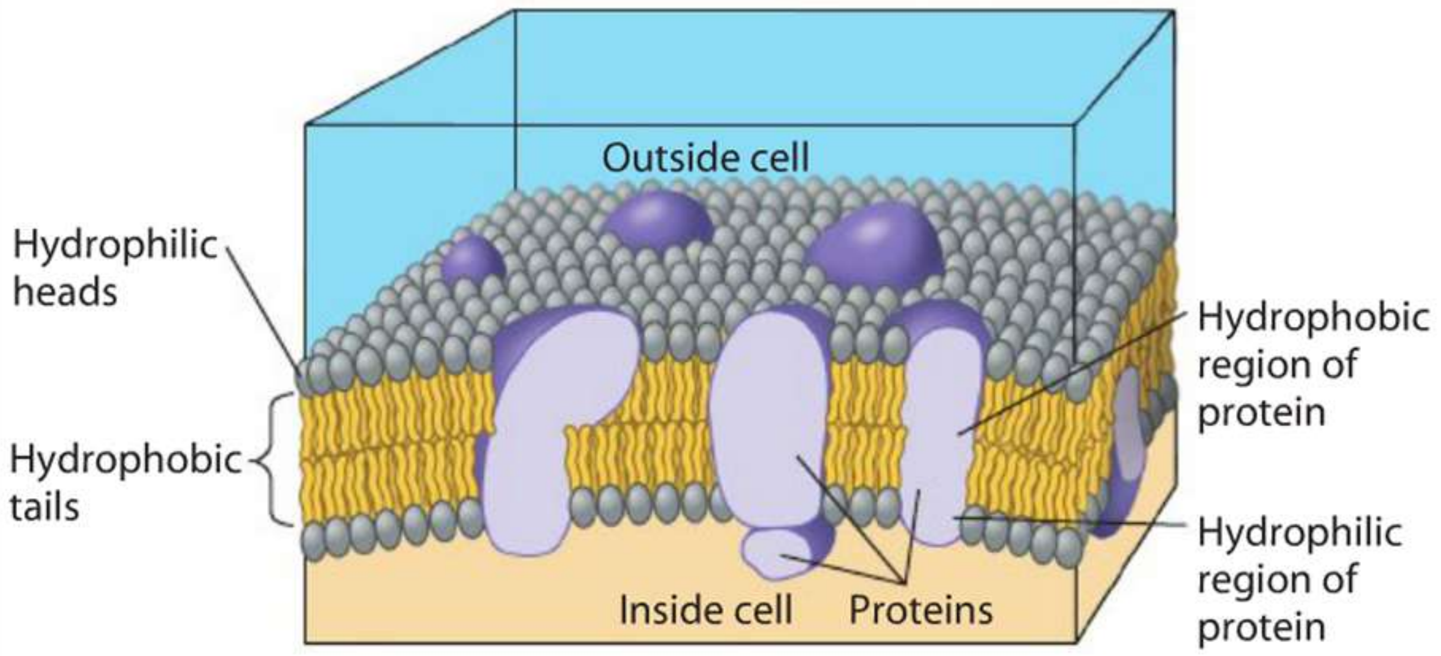
Background

What is PAA?

	Vigorox® WWT II	Proxitane® WW-12	Peragreen® 22WW
Peracetic Acid (CH_3COOOH)	15%	12%	22%
Hydrogen Peroxide (H_2O_2)	23%	18.5%	5%
Acetic Acid (CH_3COOH)	16%	20%	42-50%
Sulfuric Acid (H_2SO_4)	<1%	--	--
Water (free)	45%	balance	balance

Background
How PAA Works

- Antimicrobial mode of action has chemical specificity[1]
  - Active oxygen disrupts sulfhydryl (-SH) and disulfide (S-S) bonds in enzymes and proteins in cell membranes
  - PAA also reacts with the base pairs in DNA and RNA
- This reaction specificity results in low doses of chemical for disinfection



[1]*Kitis, M. (2004). Disinfection of Wastewater with Peracetic Acid: A Review. Environment International, (30):47-55.*

Background

How PAA Works – decay

- When added to water, PAA undergoes hydrolysis

$$CH_3CO_3H + H_2O \longrightarrow CH_3CO_2H + H_2O_2$$
$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

- When exposed to transition metal (iron) or reducing agents (caustic soda), PAA undergoes rapid decomposition

- Implications: $CH_3CO_3H + M^+ \longrightarrow CH_3CO_2H + O_2 + \Delta$
  - Prevent use of non-compatible materials
  - Prevent contamination with reducing agents
  - Prevent oxygen/heat accumulation resulting from a contamination event

Courtesy of PeroxyChem

Evaluating PAA
When is PAA Viable?

Process Operations Perspective

- Disinfection by-products are a concern
- Water has widely variable water quality considerations
- Water has high color, high TSS, or low UVT
- When nitrification or denitrification is required
- In CSO applications where chlorine is stored for long periods
  of time without use
- Safety – Move away from chlorine gas

Cost Perspective

- Capital costs are a primary driver
- Existing infrastructure supports easy conversion to PAA

Evaluating PAA

Regulatory Acceptance

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 2 5 2008

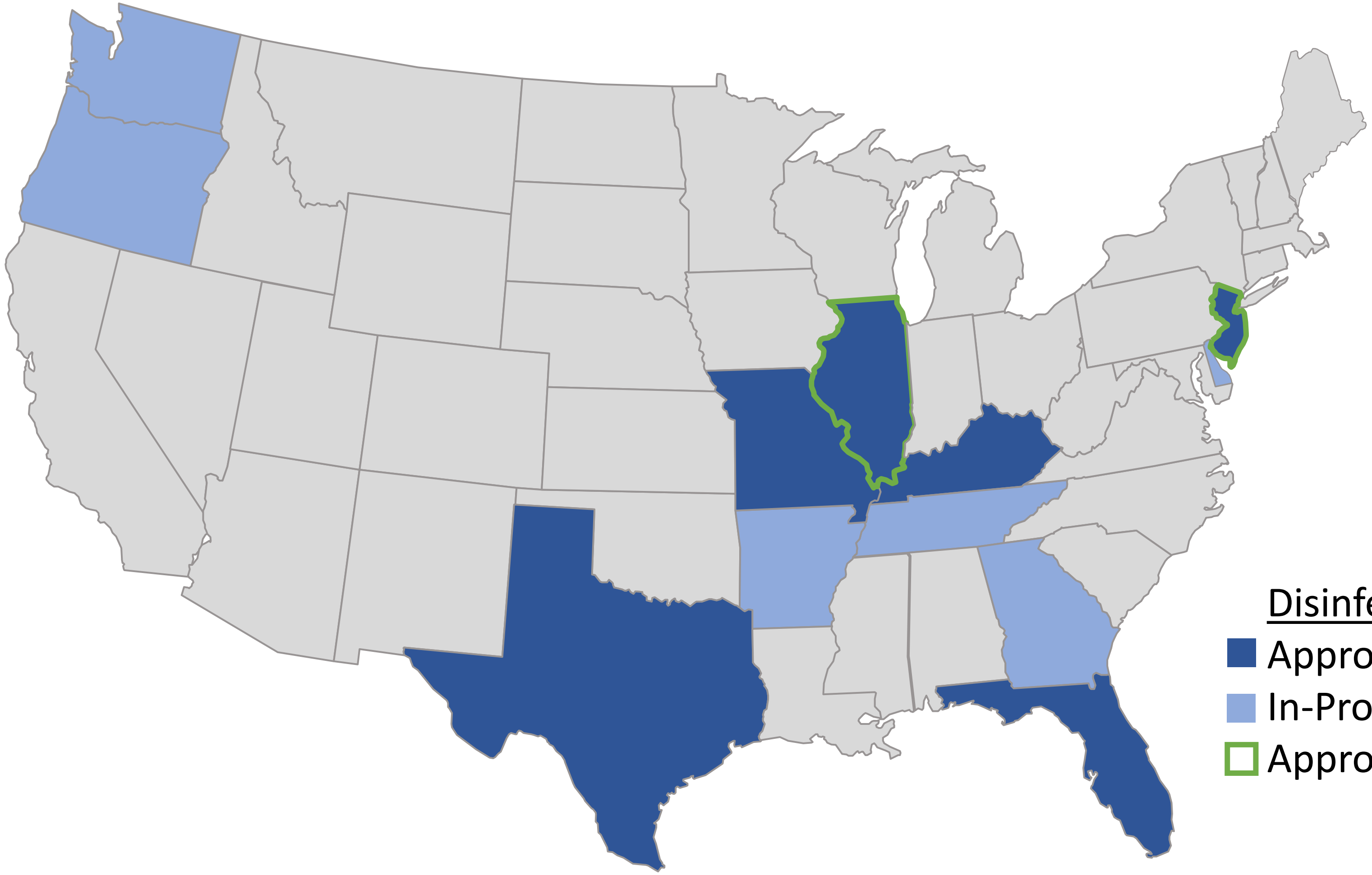
OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

Ms. Luann Maloney
Regulatory Manager for,
FMC Corporation
1735 Market Street
Philadelphia, PA 19103

Subject: VigorOx SP-15 Antimicrobial Agent
EPA Registration Number 65402-3
Your Amendment Dated December 19, 2007
EPA Received Date December 20th, 2007

The amendment referred to above, submitted in connection with under section 3(c)(7)(A) of the Federal Insecticide, Fungicide, and Rodenticide Act, FIFRA, as amended, to add directions for use in wastewater and sewage effluent disinfection in public and private treatment facilities to the product labeling, is acceptable.

Evaluating PAA
Regulatory Acceptance



- US EPA has approved PAA as a primary WW disinfectant
- Individual States also provide approval

<u>Disinfection Application</u>

- Approved Water Reclamation Modified Permit
- In-Process Water Reclamation Permit Modification
- Approved Combined Sewer Overflow Modified Permit

Evaluating PAA
Testing

Bench Testing

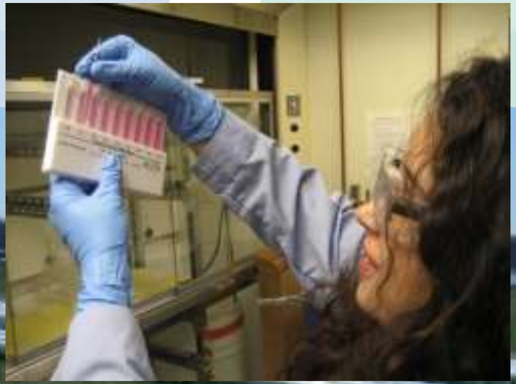
- Identifies preliminary PAA dose
- Establishes dose-response and demand/decay
- Grab samples over several days and times

Pilot Testing

- Scaled or full-scale
- Refines dose-response based upon effluent variability

Data Collection

- Flow
- pH, TSS
- Color, UVT
- Influent, effluent pathogens
- Dose, Contact Time and residual
- Water Quality Correlations



Evaluating PAA
Dose Determination

- Determine C*T (mg*min/L) value required for Log Inactivation
- Develop inactivation model
  - Many models available, most are variations of the Chick-Watson model with adjustments for first-order kinetics

Homs Model

$$ln\left(\frac{N}{N_o}\right) = -kCntm$$

- N = Organism concentration
- No = Initial organism concentration
- K = Disinfection rate constant
- C = PAA concentration
- n, m = weighting factors
- t = time

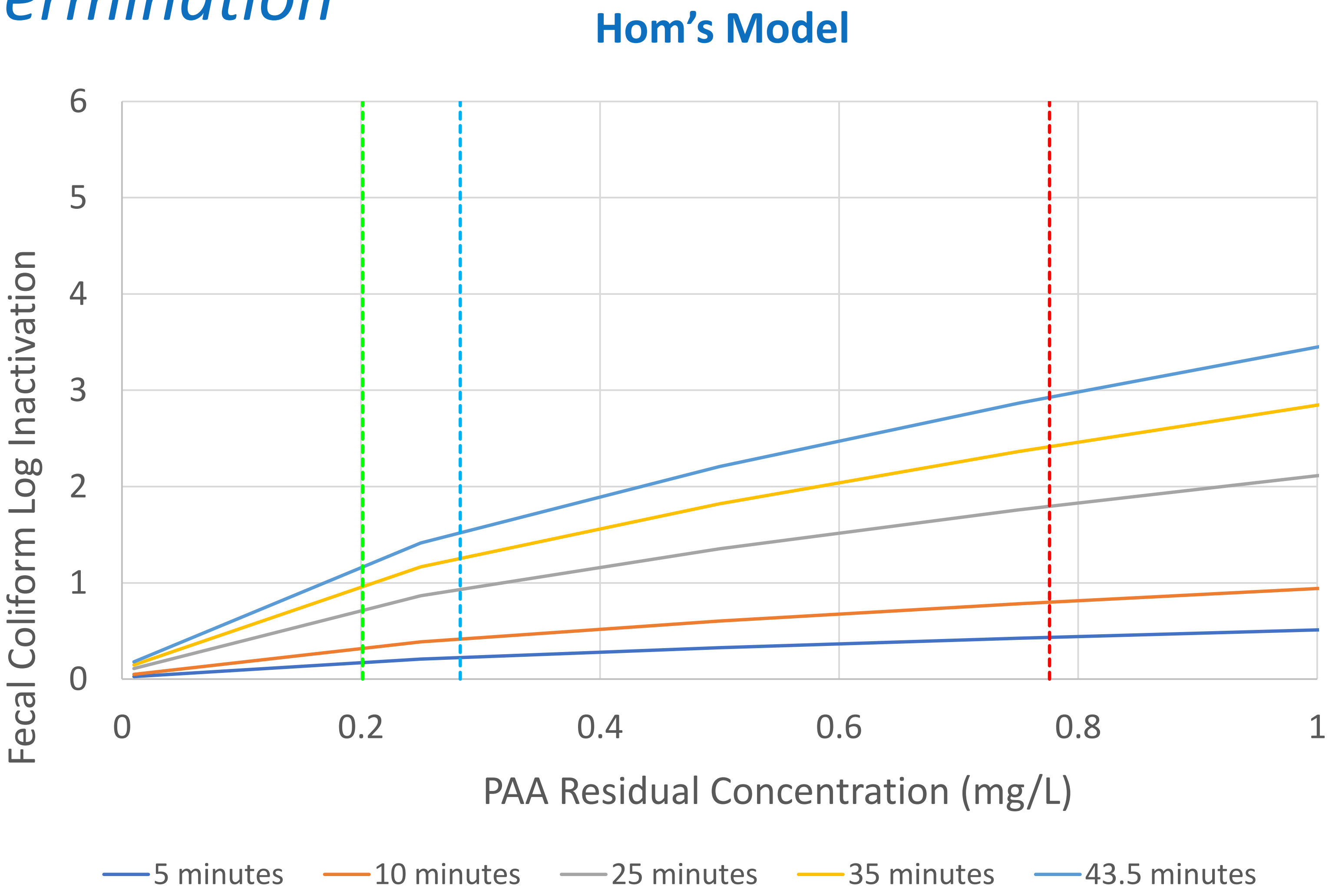
Double Exponential Model

$$N = N_o * fNd * e^{-k_d * CT} + N_o * fNp * e^{-k_p * CT}$$

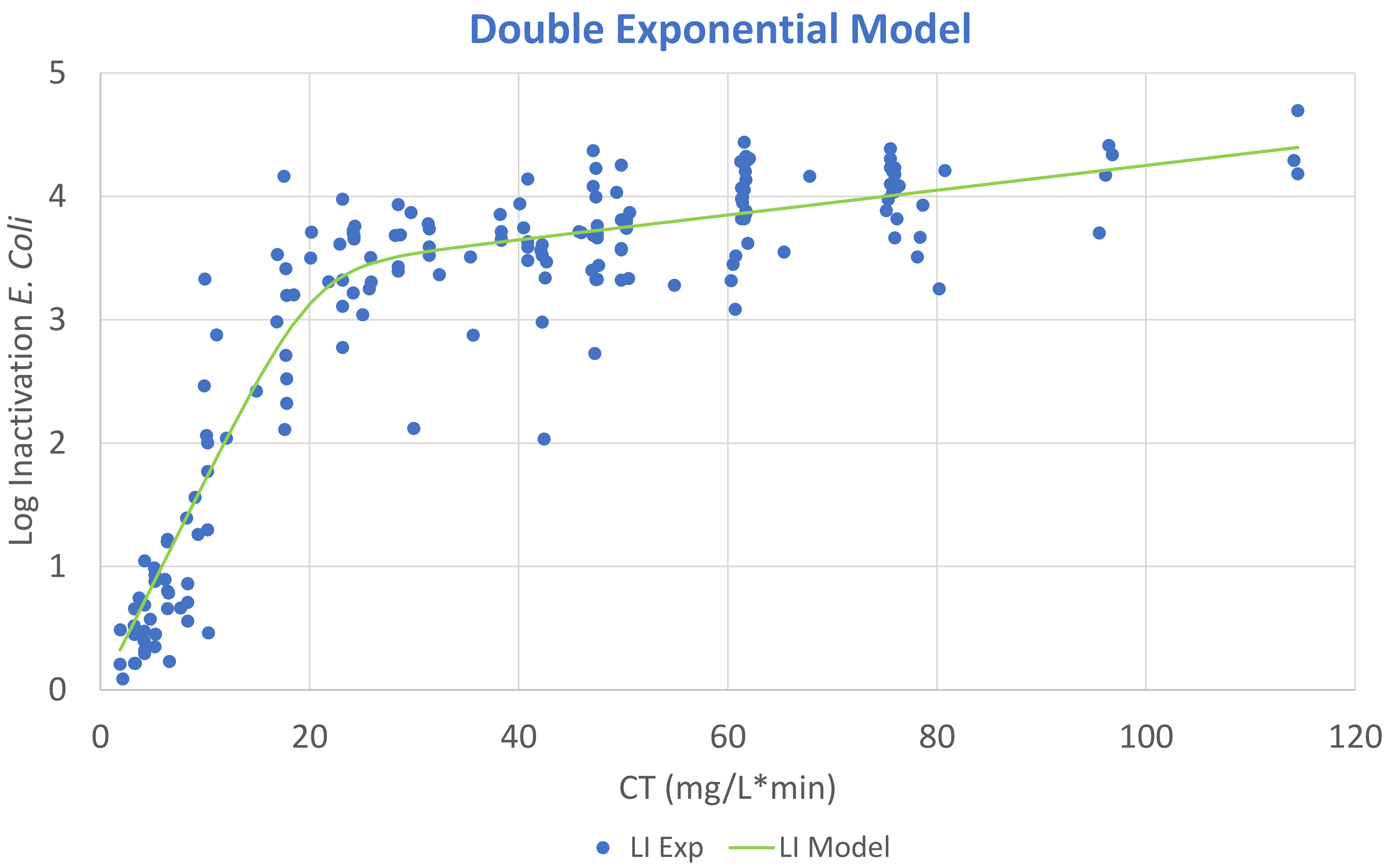
- N = Organism concentration
- No = Initial organism concentration
- fNd = the fraction of the organism population that is "easy to inactive"
- kd = the specific decay rate of the "easy to inactive" organism
- fNp = the fraction of the organism population that is "hard to inactive"
- kd = the specific decay rate of the "hard to inactive" organism
- t = time
- C = PAA concentration

Evaluating PAA

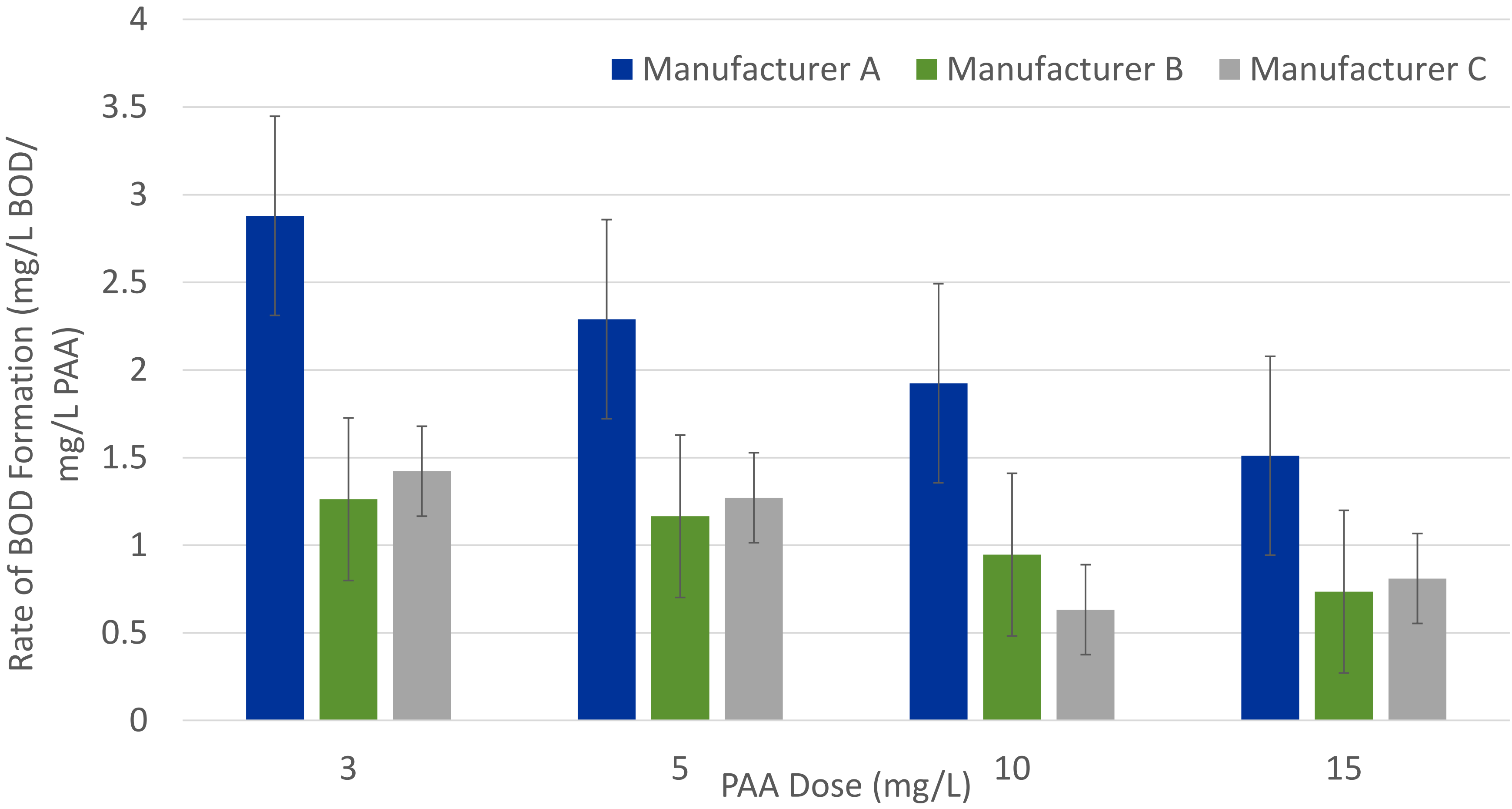
Dose Determination



Evaluating PAA
Dose Determination



Evaluating PAA
Impact on *BOD*



Evaluating PAA
Discharge Limits

- Some states have established limits for residual disinfectant
- The Vigorox® WWTII label includes recommended limits for discharge
  - 1 ppm or a calculation based on the 7Q10 of the receiving stream
- Whole Effluent Toxicity (WET) testing to verify environmental impact
  - Testing method to characterize aggregate effect of complex WW effluent
  - Acute (for applications such as CSOs)
  - Chronic (in addition to acute for NPDES)
- Quenching?
  - Not typically, but testing is required to confirm
- BE CAREFUL OF YOUR PERMIT!
  - PAA interferes with chlorine tests

EXAMPLE: Metro Vancouver

- Doses < 4.2 / 5.9 mg/L resulted in residual concentration less than LC50
- 40 WET tests were conducted during piloting and ALL met the criteria
- Method: EPS 1/RM/13 "Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout" (Environment Canada, 2000)

Evaluating PAA
Costs

- Procurement method options:
  - Purchase chemical only
  - Lease equipment and purchase chemical
  - Lease equipment, purchase chemical, and third-party operations
- Capital cost varies by site and application
- Costs for chemical vary based on amount purchased
  - $8.20 to $9.70 per gallon of solution (includes leased equipment) is a typical planning level range for a 3-5 year lease
  - Actual costs can be less

Evaluating PAA
Costs

Aspects of System Procurement:

Preconstruction services
- CFD modeling to confirm mixing efficacy
- Shop drawings

Equipment procurement
- Feed pumps
- Tanks
- Controls

Chemical purchase
- Duration
- Storage requirements

System maintenance (preventive and/or reactive)

System operation

Evaluating PAA
Costs

- System Components
- Contact Tank
- Chemical storage system
  - Storage in delivery totes
  - HDPE or passivated stainless l tanks
  - Chemical venting
- Chemical feed pumps
- Chemical injection and mixing
  - Hydraulic drop at WWTP
  - Chemical mixing or induction system
- Residual analyzers

Induction mixer (gasmastrrr.com)

Courtesy of PeroxyChem

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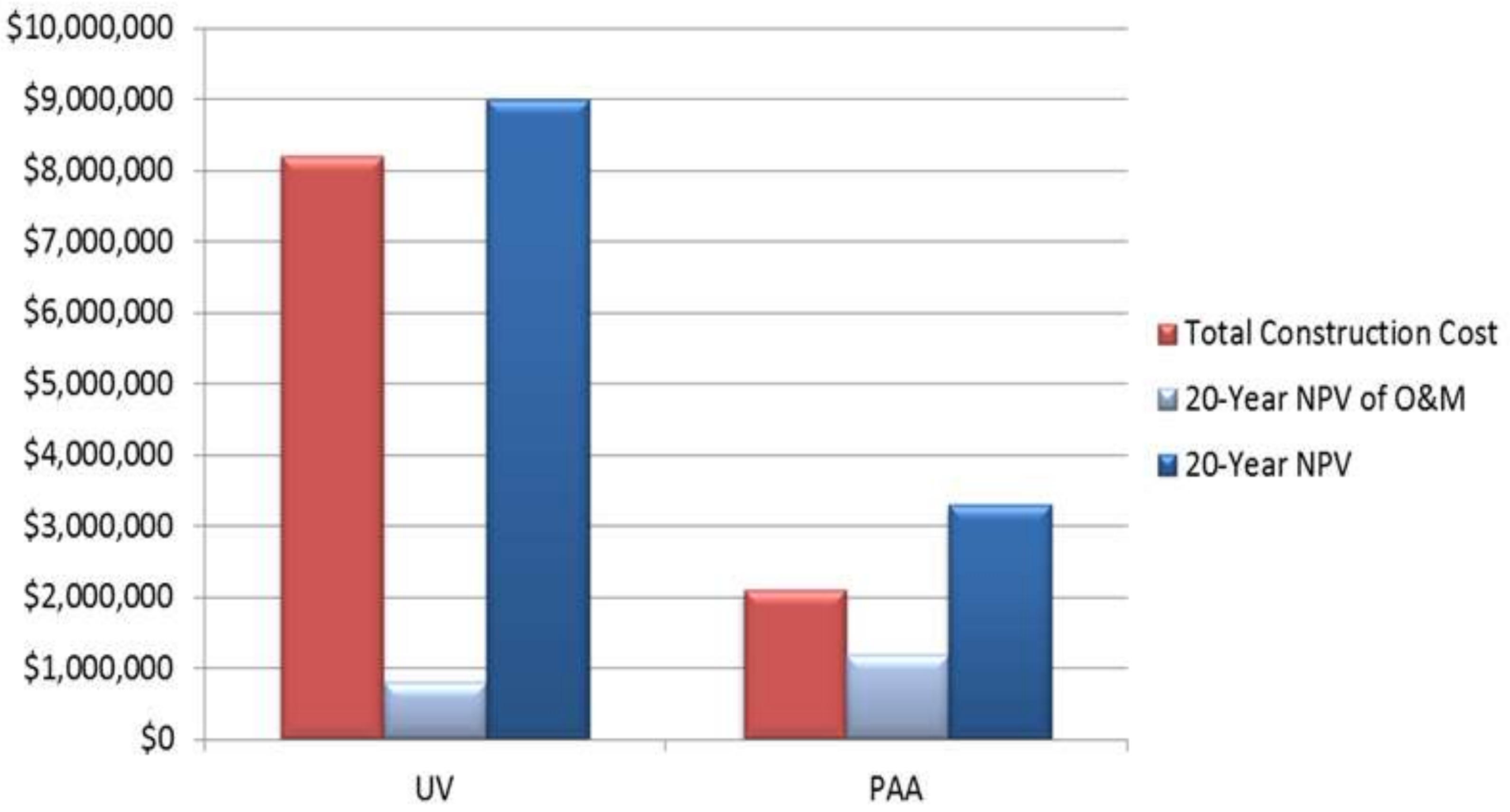
PAA Costs and Lifecycle Analysis
Case Study 1

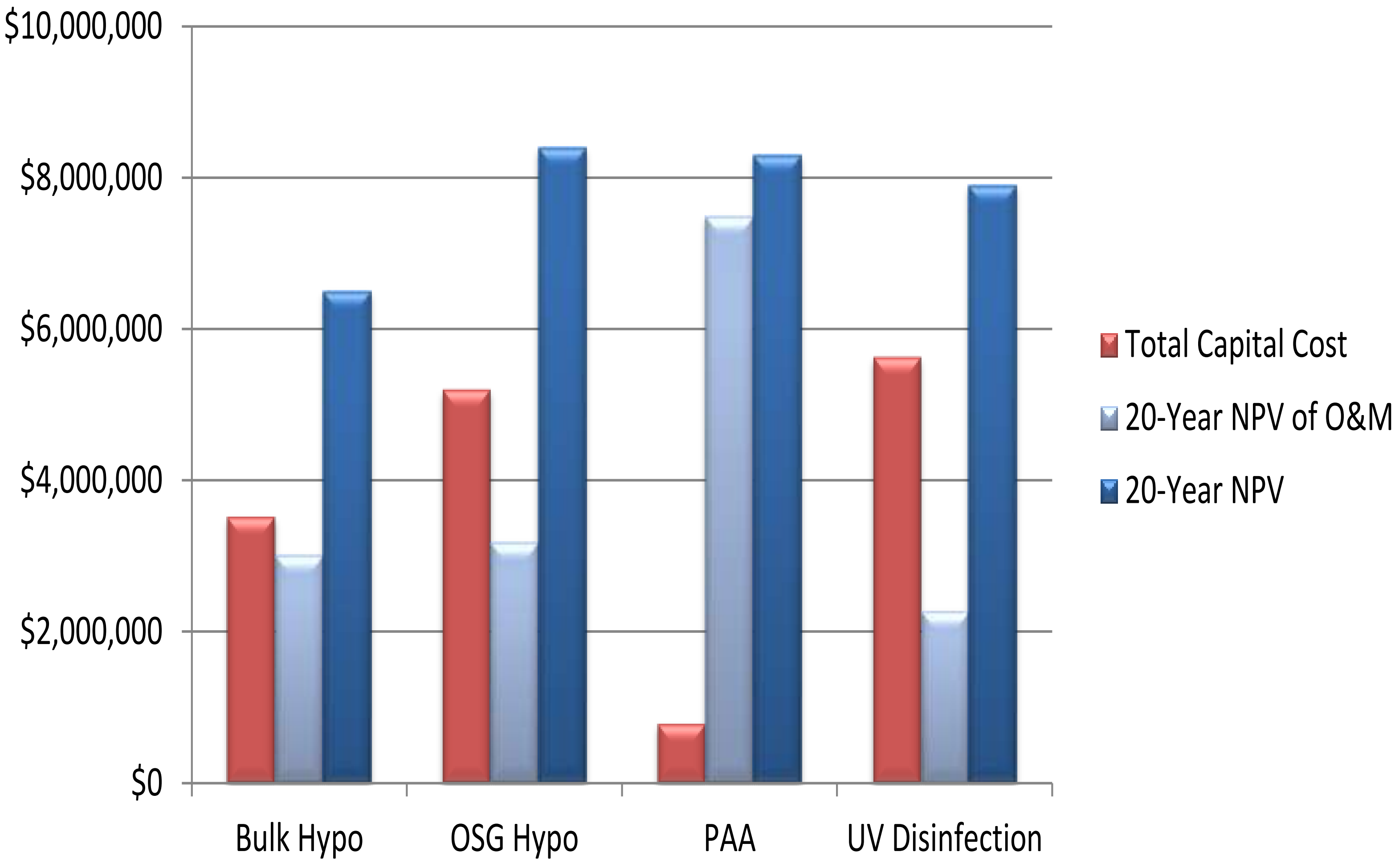
- Conventional Activated Sludge Facility
  - Tertiary Filters w/ Post Air
  - Bulk Chlorination/ Dechlori
  - Violating DBP in Permit
- ADF (mgd) = 5.5/10
- PHF (mgd) = 25



PAA Costs and Lifecycle Analysis

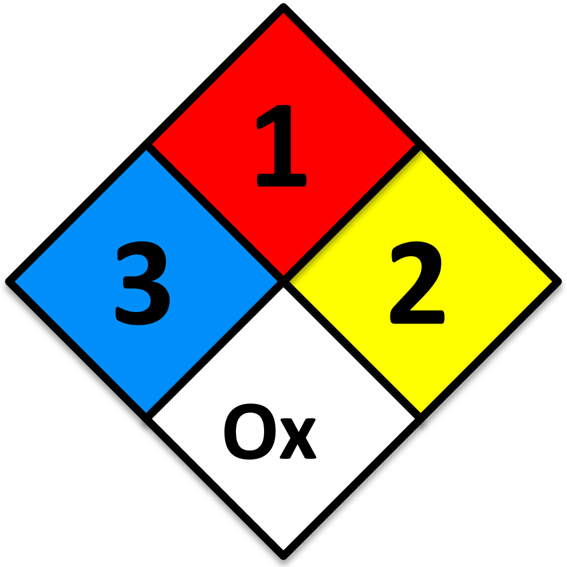
Case Study 2

- Conventional Activated Sludge Facility
  - Gaseous Chlorination/ Dechlorination
  - Moving to new technology for safety reasons
- ADF (mgd) = 25
- PHF (mgd) = 63



Evaluating PAA
Safety

- Check local building and fire codes
- NFPA
  - Health Hazard – 3
  - Flammability – 1
  - Stability – 2
  - Special Hazards - OX
- WHMIS Hazard Class
  - B3 – Combustible liquid
  - C – Oxidizing materials
  - E – Corrosive material
  - D2B – Toxic materials
- No RMP required



Courtesy of PeroxyChem

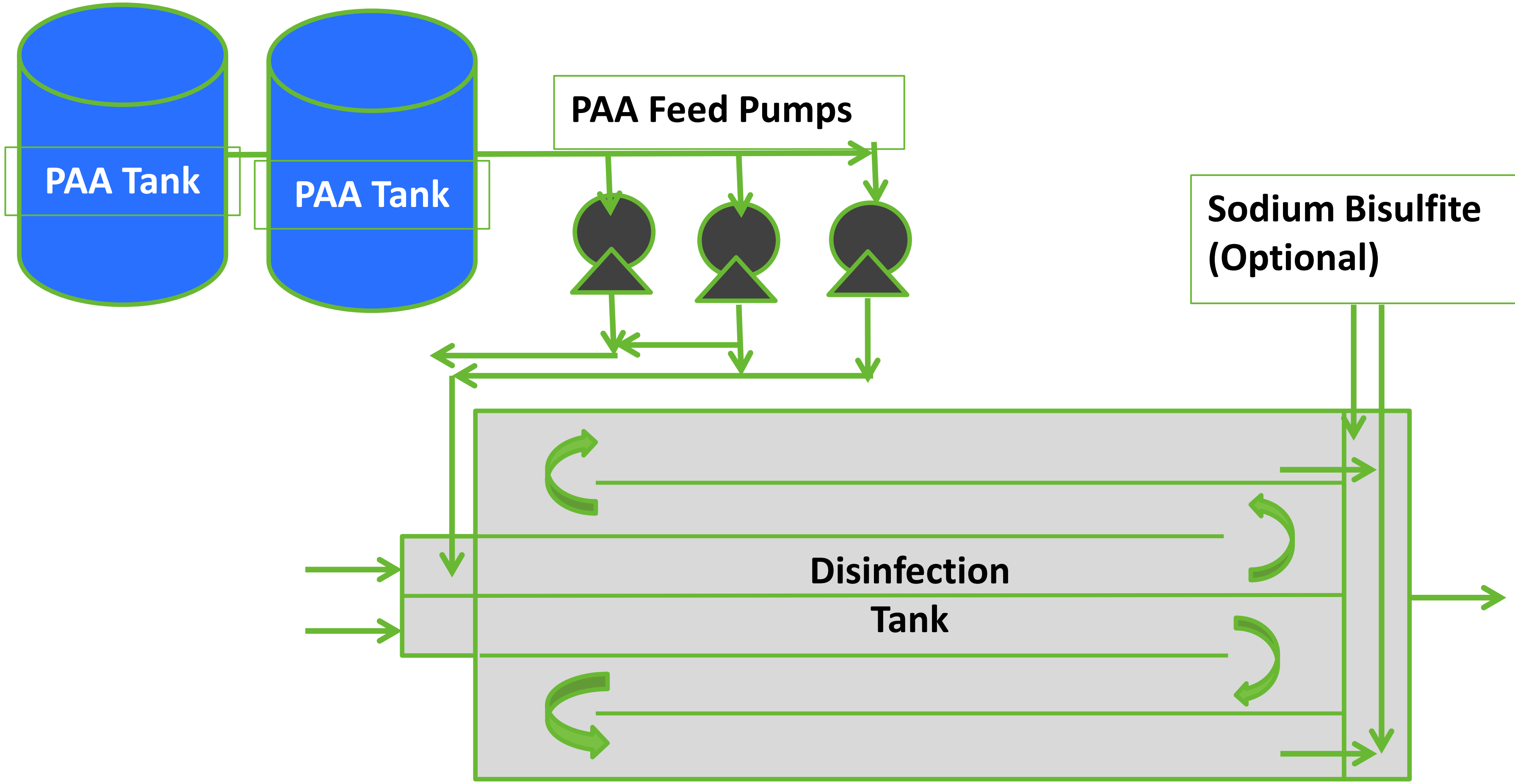
Evaluating PAA

Personal Safety

- Eye Protection — Chemical resistant goggles; face shield if splashing may occur
- Hand wear — Chemical resistant gloves (general purpose neoprene)
- Foot wear — Chemical resistant boots (no leather)
- Clothing — Chemical resistant outerwear
- Inhalation — Concentrated PAA has a strong odor and requires inhalation protection

Courtesy of PeroxyChem

Design Considerations



Design Considerations

Materials of Construction

Material	Component	Compatibility
Passivated 304L/316L SS	Storage Tank/Piping	Very Good
HDPE	Storage Tank	Moderate
Teflon	Wetted Parts	Very Good
Kalrez	Wetted Parts	Very Good
Kynar	Wetted Parts	Very Good

Design Considerations

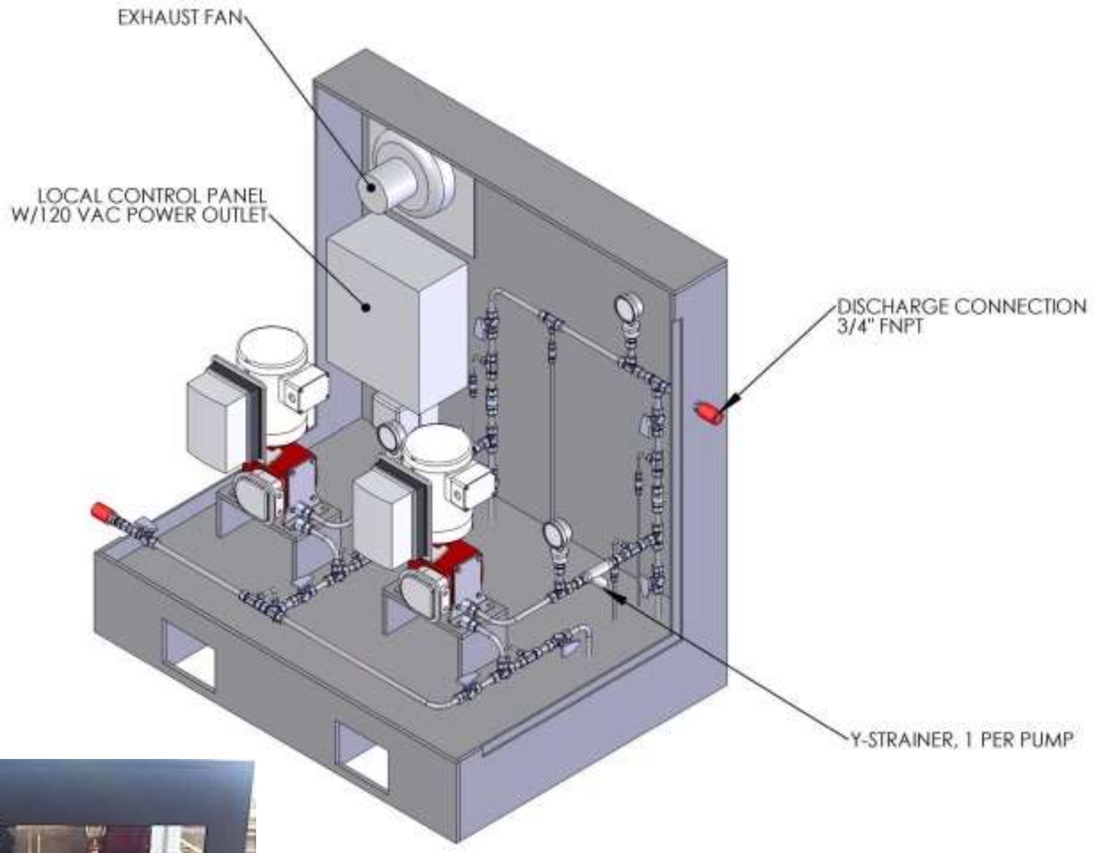
Storage

- Chemical storage system
  - 14 days of storage at average conditions
  - Storage in delivery totes or bulk
  - Chemical venting/scrubbers – *Strongly recommend*
  - Indoors or Outdoors
  - Does not need a heated space
  - Indoor IFC Thresholds
    - 25 gallons
    - Results in H3 Occupancy
    - Fire walls, automatic sprinklers, etc.
    - Check with AHJ on additional requirements

Design Considerations

Pumping

- Chemical feed and transfer pumps
  - Redundancy
  - Transfer pumps
    - Air Diaphragm or Centrifugal
  - Feed Pumps
    - Peristaltic or Gear Pumps
  - PRVs included in all segments of piping that can be isolated by valves
  - Don't use threaded connections

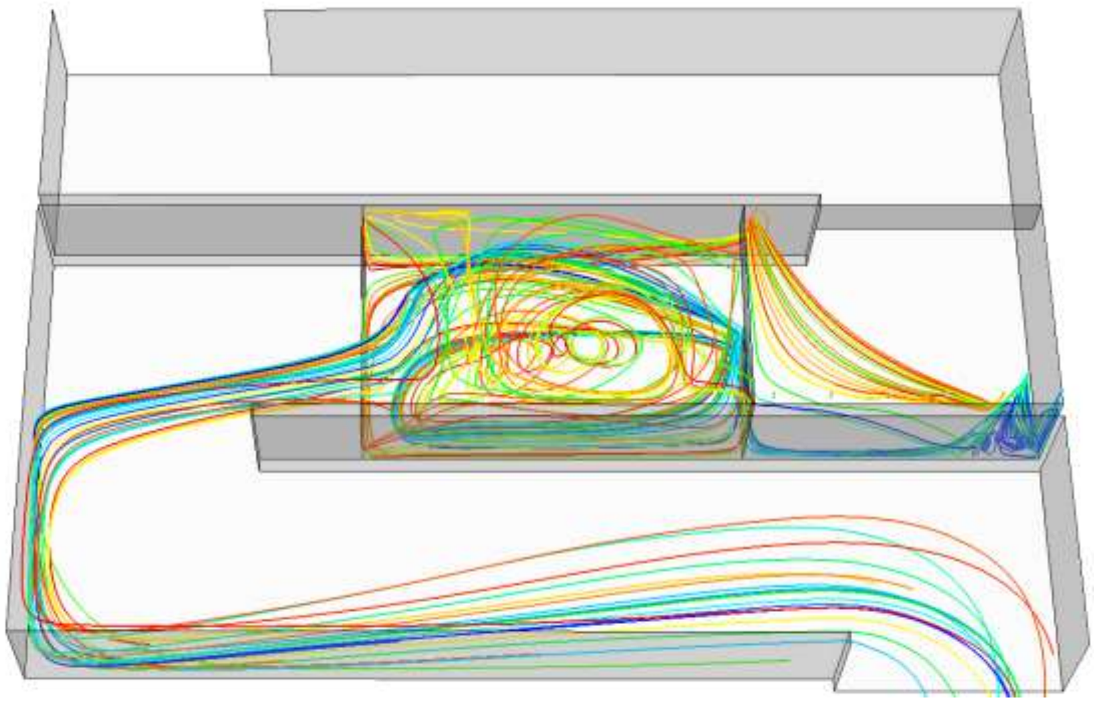


Design Considerations

Mixing

- Chemical mixing or induction system similar to hypochlorite
- Mechanical or Static Mixing
- Dilution water for mixing?
- There is a possibility to install a system without
- Consider CFD modeling

Mechanical mixer (xtolhydro.com)



Courtesy of PeroxyChem

Design Considerations

Analyzers

- Location is dependent upon control
- Similar units to chlorine analyzers with proprietary PAA analysis equations.
- CHEMetrics I-2020 PAA Single-Analyte Photometer Kit
- Tests field samples for PAA concentration

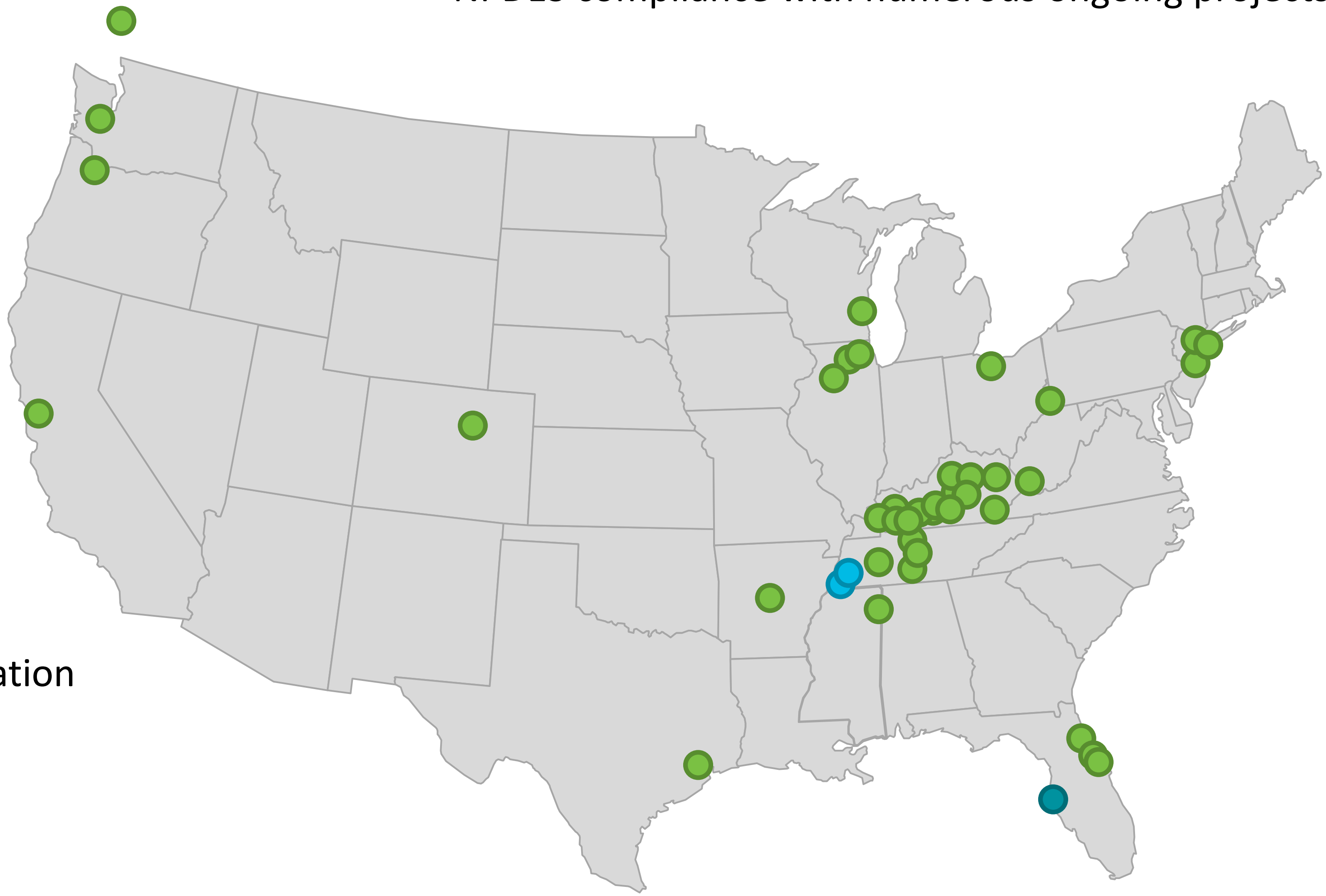
Design Considerations

Process Control

- Dose-response is site-specific
- Various process control parameters (UVT, color, COD)
- Several process control approaches are now feasible:
  - Constant dose (residual confirmed by grab samples)
  - Constant residual monitoring (single feedback loop using online analyzer)
  - Residual control including minimum dose (double feedback loop using online analyzer)
  - Pilot demonstration work ongoing
  - Requires accurate flow measurement
- Addressing bacteria growth in contact tank
  - Multiple PAA application points for various flow rates
  - Always maintain a residual

Implementation

PAA is a viable and cost-effective disinfection alternative for NPDES compliance with numerous ongoing projects



- Full Scale Operation
- In Construction
- Start-up

Summary

PAA is a viable disinfection alternative for permit compliance

Site specific parameters identified through testing

Proper basis of design considerations needed for accurate sizing of system for alternative evaluation

Challenges Remain

- Regulatory acceptance
- Process control strategies for variable effluent quality

Questions and Answers

Brian A. Hilts, PE
518-782-4504
hiltsba@cdmsmith.com